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made a careful study of the larvæ of three species and unhesitatingly places the family in the Cyclorhapha.³ These three species of *Phora* he found breeding in decaying snails, and each can be recognized in the larval and pupal condition. The author also investigates the internal anatomy of the larvæ and pupæ, and the methods of emergence of the flies.

THE full paper⁴ in which Frederic Muir solves the *Ascodipteron* question has recently been issued; a brief preliminary note appeared a year ago. Mr. Muir kept the bats containing parasites, and obtained puparia, which after about a month disclosed the winged flies. After mating, the female attaches to the bat, breaks off her wings and legs, and by the aid of the powerful mouth-parts burrows until only the tip of her abdomen remains extruded. Her body enlarges until the head is hidden within a deep anterior pit. Both new species are from the Malay region.

A RECENT entomological portion of "Das Tierreich" is by Dr. H. Friese on the megachilid bees of the world.⁵ The author tabulates the species according to the main geographical regions. Most of the species are from Europe or North America; the tables of the European species are doubtless fairly complete, but the tables for the American forms will be greatly enlarged, as many of our species are yet undescribed. In *Osmia* Dr. Friese lists 345 species, in *Anthidium* 247 and in *Megachile* 540. The work should be of great help to any one who would undertake the careful study of our megachilid bees.

ONE of the largest parts of the new "Coleopterorum Catalogus" is No. 39 on the subfamily Cerambycinae, 574 pages. It will be of the greatest use to the numerous students of this, one of the most popular families of

³ "Recherches sur la morphologie larvaire des Dipteres du genre *Phora*," *Bull. Sci. France Belg.*, XLV., pp. 27-88, 1911, 4 pls.

⁴ "Two New Species of *Ascodipteron*," *Bull. Mus. Comp. Zool.*, LIV. (No. 11), pp. 331-366, 3 pls., 1912.

⁵ "Das Tierreich," 28 Lieferung, Apidæ I Megachilinae, 1911, 440 pp.

beetles, as its author, Dr. Aurivillius, is well known as a most careful and thorough worker. In many of the larger genera the species are arranged according to the main zoological regions.

NATHAN BANKS

SPECIAL ARTICLES

SHEEP-BREEDING EXPERIMENTS ON BEINN BHREAGH¹

Introductory Remarks.—It is astonishing how ignorant we all are about common things. Just test the matter on yourself. Sheep are quite common; and we are all more or less familiar with their appearance, and should therefore be able to answer some questions about them. Well then—*How many front teeth has a sheep got in its upper jaw?*

You never counted them? You have not observed? Next time you come across a sheep just look and see, and you will find that she has *none at all!*—the upper gum is bare.

We are all familiar with the fact that a sheep suckles her young; and know therefore that she possesses nipples that yield milk. How many nipples has she, and where are they located?

Human beings, of course, have only two, located on the breast. Dogs and cats and other mammals that have a litter at birth have many nipples, located in pairs all along the belly. Cows have at least four, located on the belly between the hind legs. Where are the sheep's nipples placed, and how many are there?

I must confess that I was myself unable to answer these questions, until, in the year 1890, I made a personal examination of the sheep on Beinn Bhreagh.

¹ From the *Beinn Bhreagh Recorder*, Vol. X., pp. 368-386: A typewritten periodical, limited to five copies, containing records of experiments of various kinds, conducted at Dr. Bell's summer place at Beinn Bhreagh, near Baddeck, Cape Breton Island, Nova Scotia.

One copy is deposited in the Smithsonian Institution, at Washington, D. C., and the others are in the possession of private individuals, viz., Dr. A. Graham Bell and Mr. J. G. Davidson at Beinn Bhreagh, N. S., and Mr. Gilbert H. Grosvenor and Mr. David C. Fairchild, at Washington, D. C.

It then became obvious that sheep, like human beings, have only two nipples; and that they are located, as in the case of the cow, on the belly between the hind legs.

It was also found at this examination in 1890 that some sheep have four nipples instead of two. Two of these were in the usual place and of the usual size; the extra pair lay in front, upon the belly; and the nipples were extremely small and undeveloped, more nearly resembling pimples upon the skin than nipples. They were embryonic in character and yielded no milk.

At once interesting questions began to arise: Could we, by mating four-nippled ewes with four-nippled rams, and by selecting from their progeny for breeding purposes the lambs in which the extra nipples were most fully developed, gradually create a variety of sheep that would have four nipples of equal size, all yielding milk?

If we could, by selection, create a four-nippled variety of sheep, why not a six-nippled, an eight-nippled, or a multi-nippled variety?

It was also found in 1890 that the proportion of sheep having four nipples was larger among the twin-bearing than the single-bearing ewes; and this at once raised the question as to whether there was any correlation between the number of nipples and the number of lambs at a birth.

If the four-nippled variety should turn out to be twin-bearing, as a rule, would the six-nippled and eight-nippled varieties give us triplets and quadruplets; and would the multi-nippled ewes have a litter at birth?

Twins, etc., are usually smaller at birth than single lambs, even after they have become mature, probably because their mothers are unable to supply sufficient milk for two or more lambs when the ewes have only two functional mammæ.

Would a sheep supply more milk from four functional nipples than two; and if so, would she be able to care for two lambs as easily as one?

A twin-bearing stock, able to rear twins successfully, would undoubtedly be of great value in a country like Nova Scotia, where the win-

ters are long and the cost of sheep-breeding correspondingly great. If the farmers could raise two lambs instead of one for every ewe wintered, sheep-breeding in Nova Scotia might become a profitable industry of great importance.

These considerations led to the sheep-breeding experiments upon Beinn Bhreagh. I must here express my indebtedness to Mr. J. G. Davidson, Superintendent of Beinn Bhreagh Nursery, who has, for the last ten years, had charge of the experiments under my direction.

A Four-nippled Variety of Sheep.—By pursuing the plan of selection outlined above, we succeeded in producing upon Beinn Bhreagh, in a very few years, a four-nippled variety of sheep in which the ewes had, as a normal condition, four nipples of nearly equal size, all yielding milk.

So few cases of reversion to the ordinary two-nippled type appeared among the lambs that I felt justified in bringing the matter to the attention of the National Academy of Sciences, at their meeting in Washington, D. C., April 21, 1904.² At the same time I presented to the National Academy of Sciences, in pamphlet form, the "Sheep Catalogue of Beinn Bhreagh, Victoria County, Nova Scotia, showing the origin of the Multi-nippled Sheep of Beinn Bhreagh, and giving all the descendants down to 1903."³

This four-nippled breed was not slowly evolved by the persistent mating together of sheep having extra nipples of embryonic character. *It sprang suddenly into existence*; for it was soon discovered that it was possible to pick up here and there, from the farmers of Cape Breton Island, ewes with four functional mammæ already fully developed. These were added to our flock and hastened the accomplishment of the result.

In a few years after the experiments were begun in 1890, we had so many four-nippled sheep that we were able to cut down the flock

² See SCIENCE, Vol. XIX., p. 767.

³ This pamphlet may be found in many public libraries; the Library of Congress, Washington, D. C., Boston Public Library, the Library of the British Museum.

severely. We killed or sold all sheep with extra nipples in an embryonic or undeveloped form, and limited ourselves to ewes with four *functional* nipples alone.

After this point had been reached there were very few cases of reversion to the two-nippled type.

The flock speedily increased in numbers, and when, in process of time, it became largely composed of four-nippled sheep whose parents had also been four-nippled, the cases of reversion practically ceased and the breed was established.

At first it appeared that the four-nippled ewes were less fertile than ordinary sheep, for they had a smaller proportion of twins; but this turned out to be due to the fact that the process of selection had necessarily resulted at first in a flock composed mainly of young ewes, and young sheep rarely have twins. After the four-nippled ewes had grown to full maturity they were found to be as fertile in this respect as ordinary sheep, if not more so.

Most of the twins that were born on Beinn Breagh were small at birth. In the autumn, however, they were found, upon the average, to be fully equal in size and weight to the single lambs of the flock, thus demonstrating the important point that a breed of sheep had been produced *which could successfully rear twins*.

During the process of the establishment of the four-nippled breed the number of two-nippled and three-nippled lambs born in the flock gradually decreased; and five-nippled lambs took their place in increasing numbers. Then six-nippled lambs were produced, followed by the occasional appearance of seven-nippled and even eight-nippled lambs, indicating the possibility of producing breeds of sheep with a greater number of nipples than four, if desired.

Since the year 1890, the nipples of several thousand sheep on the island of Cape Breton have been examined, with the discovery that three-nippled, four-nippled and even five-nippled sheep are by no means uncommon. Six-nippled sheep, on the other hand, are extremely rare, only two having been discovered in twenty-two years which were not connected

with our flock. We have never come across a seven-nippled sheep that was not descended from Beinn Bhreagh stock; and eight-nippled sheep seem to be quite unknown at present outside of Beinn Bhreagh.

The fact that four-nippled sheep, like black sheep, are to be found in every flock of considerable size, led me to push the selection in the Beinn Bhreagh flock towards the formation of a six-nippled variety, so as to secure a breed that could not be easily duplicated elsewhere.

Origin of the Six-nippled Variety of Sheep. (Ewe No. 76.)—As early as 1891 we discovered in the flock of a farmer a six-nippled ewe, with the four extra nipples very poorly developed. We purchased her and added her to our flock as "No. 76," as she was a yearling at the time.

She remained on Beinn Bhreagh for several years and gave us nine lambs in all before she died. She was mated with our best four-nippled rams, but never gave us a six-nippled lamb. The first six-nippled lamb born on Beinn Bhreagh, however (No. 610), was her direct descendant (granddaughter) without any admixture of other six-nippled blood; and the ewe, No. 610, gave us a six-nippled lamb when she was only a year old herself.

No. 76 was a white ewe, and in 1893 she was mated with a white ram, but the lamb she produced in 1894 was black. He turned out to be a ram with four nipples (No. 417), and he is largely responsible for the black blood that afterwards appeared in the Beinn Bhreagh flock.

(Ewe No. 256.)—In the course of that same year (1894) we heard of another six-nippled ewe which had been discovered in the flock of a farmer near North River, St. Ann's; but she was so wild that the people on the farm were unable to catch her for us.

As we desired to secure her before the breeding season arrived, we sent a man to the farm two or three times to assist in her capture, but all without success. She was as wild as a deer and leapt the fences and escaped to the woods.

Finally a large expedition was sent about October, 1894. The hunt occupied the greater part of a day, and at last the men succeeded in driving the ewe into a place from which there was no escape, and she was brought to Beinn Bhreagh and added to our flock as No. 256.

She turned out to be a black ewe, two years old, with six well-developed and functional nipples, well arranged in pairs. She was mated with the black ram No. 417 (the offspring of the other six-nippled ewe No. 76), so that any lamb she might have would combine the blood of the two six-nippled ewes, No. 76 and No. 256.

Of course the results of the union were eagerly looked for, but in the spring of 1895 the ewe, No. 256, escaped and lambed in the woods.

Then there was a hunt to save the possibly six-nippled lamb from the foxes that had occasionally taken toll of our flock. It took quite a large number of men, in skirmishing order, to re-capture the run-away, but the lamb turned out, after all, to be a black ewe *with only four nipples!*

Although the black six-nippled ewe (No. 256) lived for many years on Beinn Bhreagh, and gave us twelve lambs in all (including, by-the-bye, five sets of twins) we never got a six-nippled lamb from her—unless indeed her lamb No. 940 might be so considered.

This lamb (No. 940) was at first noted as a five-nippled ewe; but one of her nipples, instead of being round like the others, was greatly elongated in cross section, and had two distinct orifices. It was evidently formed by the union of two distinct nipples into one. After lambing, both of the Siamese-twin nipples were found to yield milk; and we have the ewe now recorded on our books as a six-nippled sheep.

In the autumn of 1895 the black six-nippled ewe No. 256 was again mated with the black four-nippled ram, No. 417; and in the spring of 1896 gave us black twins; one, a female with four nipples, and the other a male, No. 626, with five nipples.

This five nipple ram, No. 626, not only represented an advance in nipples over rams formerly employed; but, in addition, he combined in his own person the blood of the two six-nippled ewes, No. 76 and No. 256. He was, therefore, although black, used very extensively with the flock until white six-nippled rams appeared among his offspring, when they were substituted as the sires of the flock.

No. 810 and No. 827 (born 1898) were the first six-nippled rams employed in the flock; and six-nippled rams have been used ever since. In 1899, 25.6 per cent. of the lambs born were six-nippled, but in 1900 the percentage, for some unaccountable reason, fell to 4.4 per cent.; and the percentages in succeeding years, 1901, 1902 and 1903, were only 9.4 per cent., 9.6 per cent. and 11.1 per cent., showing a very slow rate of increase in spite of the fact that six-nippled rams had been used exclusively in the flock since the autumn of 1898.

There had been no difficulty in producing the four-nippled variety of sheep, because we had been able to obtain from surrounding farmers sheep with four nipples already fully developed to add to the flock, but in the case of the six-nippled variety we were unable to obtain this aid from the farmers.

No six-nippled sheep were to be had for love or money. We advertised for them and offered large prices. We notified butchers to examine the nipples of the sheep that came to them for slaughter, etc., but all in vain. During a period of thirteen years from the purchase of ewe No. 256, the only six-nippled sheep we were able to buy was a black ewe, No. 735, with very poorly developed extra nipples, which had been found by a butcher in Baddeck among the sheep purchased from farms in close proximity to Beinn Bhreagh, and which probably represented a leakage from our flock.

It will thus be seen that, as we were unable to obtain six-nippled blood from outside, the only way we could advance the formation of a six-nippled variety of sheep seemed to be: (1) To use six-nippled rams on the whole flock; (2) to select from the six-nippled ewes

born on the place those that had the most fully developed extra nipples, discarding the others.

The second plan seemed to be impracticable on account of the small number of six-nippled ewes that made their appearance. We had perforce to keep all the six-nippled ewe lambs that appeared in order to preserve the six-nippled strain from the danger of extinction. No selection by six-nippled ewes was possible; and the bulk of the flock remained four-nippled for years in spite of the continual use of six-nippled rams.

Females More Important than Males.—We recognized the fact that we were breeding for a female peculiarity; and that in this case selection by females was probably more important than selection by males.

In the hope of increasing the number of lambs from which selection could be made we determined to enlarge our flock; and, in the autumn of 1903, we purchased several four-nippled sheep and a large number of ordinary two-nippled ewes, and used our six-nippled rams with the whole flock. This plan increased the number of lambs born in 1904 and reduced the percentage of six-nippled sheep to 4.8 per cent.

After one winter's experience it became obvious that it was inadvisable to have a large flock on account of the increased expense and the difficulty of preserving accurate records with large numbers.

In the autumn of 1904, therefore, we cut down the flock to one half; retaining only ewes having four or more functional nipples, and in the spring of 1905 the percentage of six-nippled lambs rose to 25.8 per cent.; followed by 23.6 per cent. in 1906, and 27.7 per cent. in 1907.

It was speedily realized that with a small flock continuous inbreeding was inevitable; and that it would be very advisable to introduce new blood, as the flock was undoubtedly deteriorating physically. The difficulty, however, was that no six-nippled sheep could be found outside our own flock. We searched the country far and wide, and offered fancy prices without any success.

Avoiding the Evils of Inbreeding.—In the autumn of 1906 we tried the experiment of loaning a six-nippled ram to a neighboring farmer; and we offered him \$10.00 apiece for any six-nippled lambs produced, \$15.00 for seven-nippled and \$20.00 for eight-nippled lambs. As the result of this experiment we were able, in 1907, to purchase two six-nippled lambs.

The experiment of loaning a ram was tried again in the autumn of 1907, with the result that in 1908 we were able to purchase four six-nippled lambs, for which we paid the farmer \$40.00. This excited the interest of other farmers, who now began to apply for the loan of our rams under similar conditions of payment for lambs.

This plan of loaning rams turned out to be a success; and by the autumn of 1909 it became obvious that, by pursuing this plan, we could rely upon surrounding farmers for a continual supply of new six-nippled blood without keeping a large flock ourselves.

Giving up the Four-nippled Breed.—In the autumn of 1909, therefore, we cut down our flock to six-nippled ewes alone, and distributed our four-nippled and five-nippled ewes, as a bonus, among the farmers who would use our rams.

In the spring of 1910, 50 per cent. of the lambs born on Beinn Bhreagh were six-nippled; and we were also able to purchase a number of six-nippled lambs from the farmers. Very similar results were obtained in 1911.

This spring (1912) 53.6 per cent. of our lambs were six-nippled; and the records handed in by the farmers who have used our rams indicate that we shall probably be able to purchase from fifteen to twenty six-nippled lambs this year.

The New Departure.—As it has now been demonstrated that we can rely upon a constant influx of new six-nippled blood from outside, the time has come when we may begin the selection of six-nippled sheep by females. We propose to cut down our small flock still more this year, and keep only six-

nippled ewes that have all six nipples in a functional condition. We fully expect an increase in the percentage of six-nippled lambs born on Beinn Bhreagh next year, in spite of the fact of the large amount of alien blood in the flock. The new blood introduced has not diminished the proportion of six-nippled lambs born on the place, while it has resulted in increased vigor and strength in the flock as a whole. The physique has been improved to such an extent that there are now no better nor finer sheep than those to be found on Beinn Bhreagh.

A Discovery Relating to Color.—During the course of our breeding experiments a very curious fact made its appearance. It is well known that when white ewes are mated with white rams, black lambs occasionally appear among the offspring; but it has not hitherto been known that when black ewes are mated with black rams, the offspring are always black.

This fact was discovered by Dr. Davenport, Director of the Carnegie Institution's Station for Experimental Evolution at Long Island, N. Y., from a study of the records of the Beinn Bhreagh flock; and his conclusions have since been amply verified at Beinn Bhreagh and elsewhere.

Production of Twins.—The experience of the past has shown that twin lambs are usually the produce of old ewes; and the fact that 36 per cent. of the lambs born on Beinn Bhreagh are twins is very encouraging when we consider that they are the produce of young ewes.

We are getting twins from mothers that were only one year old, and two years old, at the time of the birth of their lambs; and 60 per cent. of the lambs born this spring from three-year-old ewes were twins.

We have only one old sheep on the place, No. 1505. She was seven years old this spring and has given us eleven lambs to date. She started out with twins when she was only a lamb herself (one year old) and has given us three sets of twins since then, besides three single lambs.

The indications are that our six-nippled

stock will ultimately turn out to be twin bearers, as a rule, when they become fully mature.

In the meantime the question is: What can we do to favor the production of twins in our flock?

1. One point of importance will be to see that twin ewes are mated with twin rams.

2. Twin-bearing ewes are, on the average, much heavier than single-bearing ewes. We would therefore favor the production of twins by weeding out from the flock, while still young, ewes that are markedly under the average weight of the ewes of their age.

3. When our flock of adult ewes is large enough to permit of selection it might be well to discard ewes at the age of three years, at all events at four, if they have never given us twins; so that the bulk of our fully mature females should ultimately be composed of ewes that have produced twins when young.

These points relate to efforts to increase the hereditary tendency to the production of twins; but there are other points relating to environment which are also of importance.

Condition of Nutrition Important.—The records of weight that have been preserved at Beinn Bhreagh seem to indicate that the condition of nutrition of the mother at the time of mating has an important influence upon the conception of twins. Our records show that the twin-bearing ewes increase in weight as the mating period approaches; and that mating occurs when the ewes are in prime physical condition.

This probably explains the curious fact that the ewes, which are mated in October, have a much larger proportion of twin lambs than those which are mated later on in the breeding season; thus verifying the old saying of the farmers here that "March lambs bring twins." The pasture is at its best in October. It begins to fail in November, and by December there is very little left. Our records show that when ewes are mated in October the proportion of twins born is larger than when mating occurs in November, and that very few of the ewes mated in December have twins.

In order to favor the production of twins it is therefore necessary, or at least advisable,

that the ewes should be in prime physical condition at the time of mating.

To secure this point we breed in October; and it has also been our custom for some years past to provide the ewes with extra nourishment in the form of oats, oil-cake, etc., for two or three weeks before mating.

In order to be perfectly sure that each ewe receives her proper share, individual feeding pens have been provided.

When a common trough is used the larger and stronger sheep, who need it least, get most of the food; and the smaller and weaker, who need it most, get least.

Nutrition After Mating.—Our records of weight indicate that there is a characteristic difference in the weights of twin-bearing and single-bearing ewes after mating.

The twin-bearing ewes, on the average, show a marked and even sudden dropping off in weight within two or three weeks after mating, which is not found in the case of the average single-bearing ewe.

This may be translated to mean *lowered nutrition after mating as a characteristic of the twin-bearing ewe*; and a consequent lessening of the growth of the unborn lambs, so that when the twin lambs are ultimately born they are of smaller size and weight than the average single lamb.

We sometimes find that twin lambs are very unequal in size at birth. If one is large the other is likely to be small and even deformed, indicating a struggle for existence between the unborn lambs.

This led me to suspect that many of our largest single lambs might be the survivors of twins; and a few years ago I had a young physician from Washington (Dr. Phelps) visit Beinn Bhreagh at the lambing season to see what he could discover bearing upon the point.

He was able to examine quite a number of the after-births of the sheep; and in several cases where single lambs had been produced he found indications in the after-birth of an aborted twin.

In this connection it is suggestive that our best twin-bearing ewe, No. 1505, which has

given us already four sets of twins, produced this year a single lamb *weighing ten pounds at birth!* It is notorious also, that fat stock are remarkably infertile, and rarely bear twins.

All these considerations led to the belief that lessened nutrition during the period of gestation is a condition that is favorable to the preservation of unborn twins. Good nutrition at the time of mating favors the *conception* of twins; and diminished nutrition after mating favors their retention.

It is obvious, upon reflection, that ewes can not successfully bear twins, or a litter at birth, unless the lambs born are small; and lessened nutrition during the period of gestation is eminently favorable to the production of lambs that are small at birth.

These considerations led to the policy of giving the ewes extra nourishment in the form of oats, oil-cake, etc., for some time before mating; and then cutting off the extra feed soon after mating so as to throw the ewes back on the pasture alone for support.

A better, and certainly more economical plan, affecting the condition of nutrition in the same way, would be simply to mate in October when the pasture is at its best, and then give hay alone for winter feeding. The giving of oats, oil-cake, roots and other milk-promoting food might well be postponed until about the time of lambing, so as to avoid stimulating the growth of the lambs until after they are born.

In order to raise twins and triplets successfully the lambs should be small at birth, and grow large afterwards.

If we had a large number of twins from which to choose, it would be a good plan in the spring to retain only those lambs which are under the average weight at birth; and then, in the autumn, select from these those that are over the average weight. This process carried on through a series of generations would probably result in a breed of sheep producing, as a normal condition, lambs that are small at birth and which grow large afterwards.

ALEXANDER GRAHAM BELL